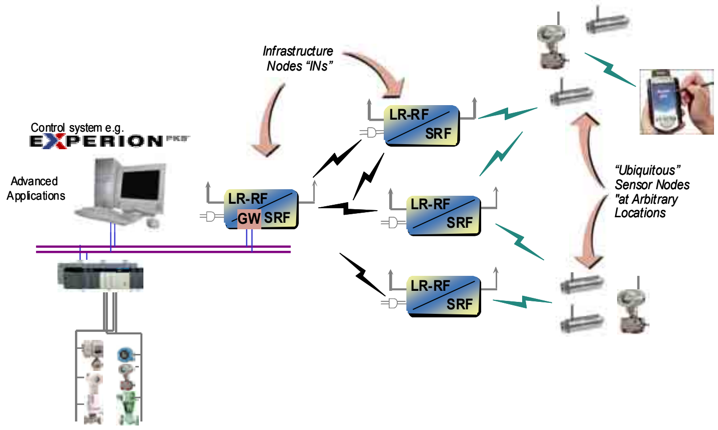
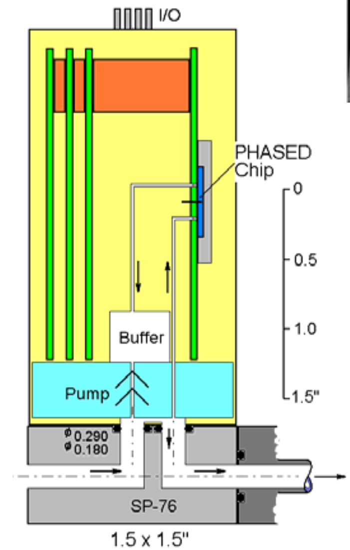
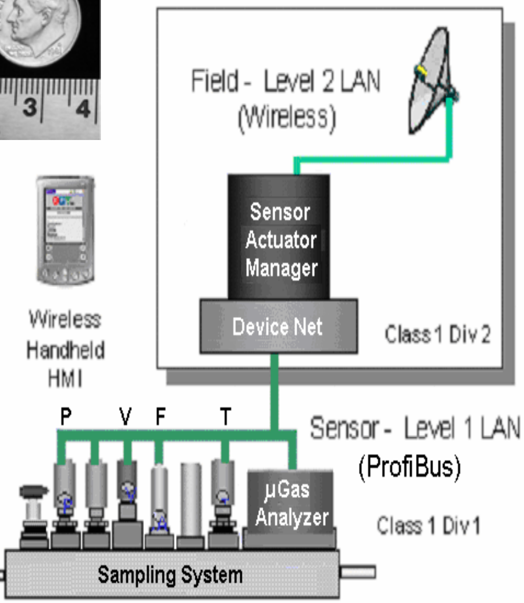
Wireless and Sensing Solutions Advancing Industrial Efficiency







Honeywell

Steve Huseth
Honeywell Laboratories

DOE S&A Review
June 21, 2004

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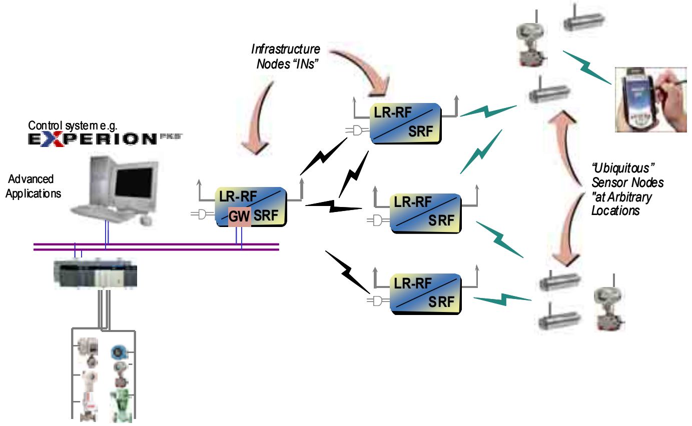
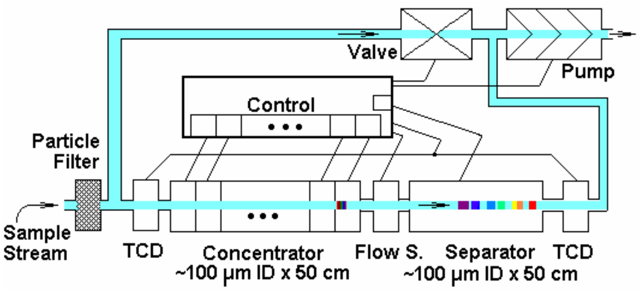
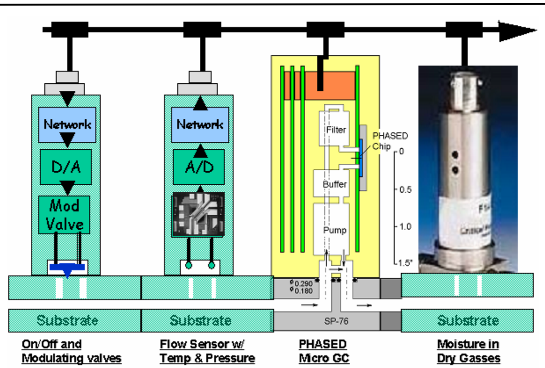
Wireless and Sensing Solutions – 3 Technologies



Wireless Network for Industrial Applications
- Robust industrial wireless infrastructure
- High data security
- Lowest total cost of ownership
- Low power requirements and extended battery life
- Enhanced availability and coexisting with other RF systems

PHASED Gas Composition MicroAnalyzer
- MEMS based micro gas chromatograph
- Real-Time, online measurement of process chemistries
- Low Power requirements
- Short analysis time





NeSSI-Compatible Microanalytics
- Validate NeSSI-II and NeSSI-III design
- Test modular, networked, intrinsically safe sampling and measurement platform in operational industrial environments

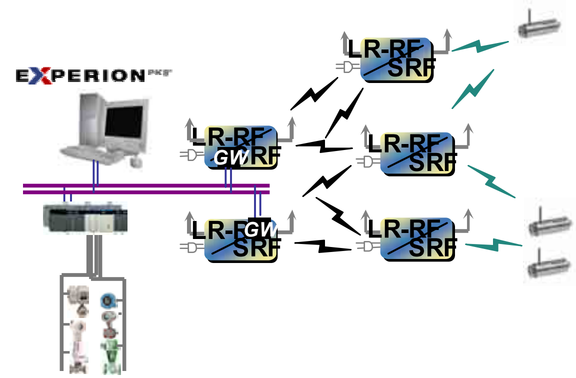
Wireless and Sensing Solutions Advancing Industrial Efficiency

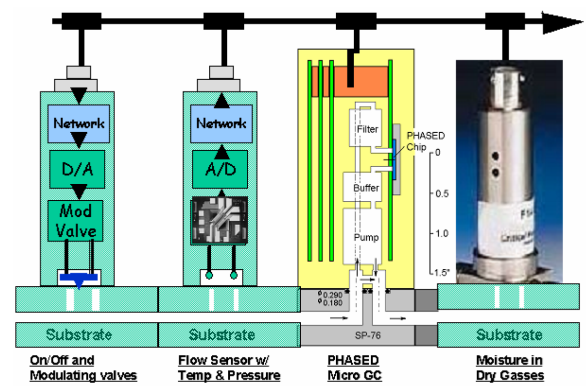
Goal: Design, develop and demonstrate a wireless sensor communication architecture with significantly enhanced robustness, speed, security and reliability. Develop and demonstrate preconcentration and composition analysis of gaseous process streams on a modular, intrisically safe process stream sampling system.

Challenge: Wireless communication of sensor data must be “as good as a wire”, maintain high data security and integrity, yet minimize end user cost of ownership. Industry requires gas composition analyzers of reduced size, cost, maintenance, and analysis time, of increased sensitivity, and no carrier gas requirements.

Benefits: Enable improvements in process control by providing low-cost, reliable measurements at key points, particularly in energy-intensive processes, resulting in lower energy usage per unit of product produced across a wide range of industries.

FY05 Activities: Design and develop multiple wireless leaf and network node designs. Validate enhanced robustness and performance against customer CTQs. Design and integrate PHASED with on-chip detectors. Test and characterize performance.





Participants: Honeywell, Adcon, Omnex, Ember, NTRU, ChevronTexaco, B4HI, EPRI, NIST, DuPont, Caviton, CPAC, DowChemical, UOP, ExxonMobil, Air Products, Univ. of Washington - CPAC

Wireless and Sensing Solutions Advancing Industrial Efficiency

Barrier-Pathway Approach

Barriers

- Ability to provide highly reliable RF communication in the presence of environmental interference and other RF systems.
- Insufficient stability, resolution, sensitivity and analysis range with absorber materials.
- Ability to pass intrinsically safe certification in complete compact package that will plug onto NeSSI substrate.

Pathways

- Robust wireless communication architecture. Critical assessment of multiple approaches.
- Development of PHASED Micro-GC analyzer based on MEMS technology.
- Low power intrinsically safe NeSSI platform as a standardized sensing platform.

Critical Metrics

- Sensitivity of RF network to interference, failure modes. Assessment against CTQs
- GC analysis down to 0.01 to 1 ppm level within 3 seconds w/o carrier gas and power of less than 10 J/analysis

Benefits (est.)	2020
Sensing and Sampling (gas composition)	**254 trillion Btu**
Pervasive Wireless Sensors	**190 trillion Btu**

Progress to Date – Industrial Wireless

- **Completed Voice of Customer with multiple industry segments**
  - Chemical
  - Power Generation
  - Petroleum Refining
- **Completed initial requirements specification to meet industrial wireless sensor networks CTQs.**
- **Completed design of first wireless network strategy and nearing completion of second strategy that will be tested against CTQs**

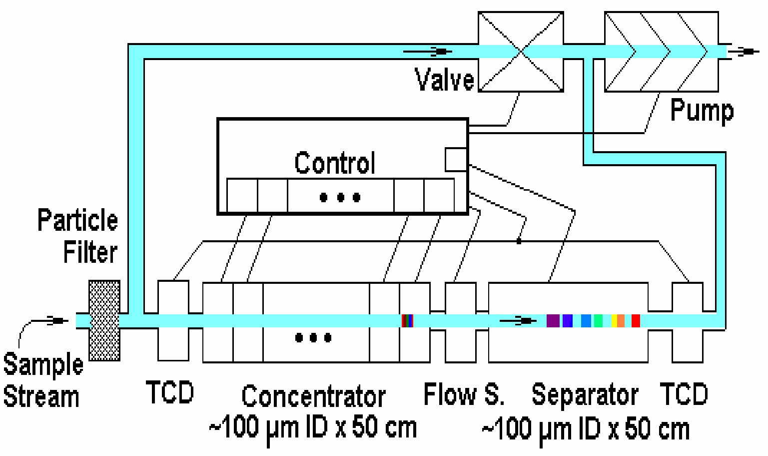
Progress to Date – PHASED Micro Analyzer

Preconcentration

- Output Peak Height:
  - Increases as heater pulses increase in temperature
  - Reaches max. height when pulse rate is in synch with flow
  - Agrees qualitatively with modeled behavior
- PC Factor:
  - Increases with pulse height and number of elements
  - Values > 80:1 @ 70°C with H_2O (pk./depl.)

Separation

- Retention time depends on T and mat'l., not on film thickness distribution
- Retention and resolution of candidate stationary phase is comparable to DB-5
- Determined 40-55 kJ/mole heat of adsorption on Honeywell porous silica

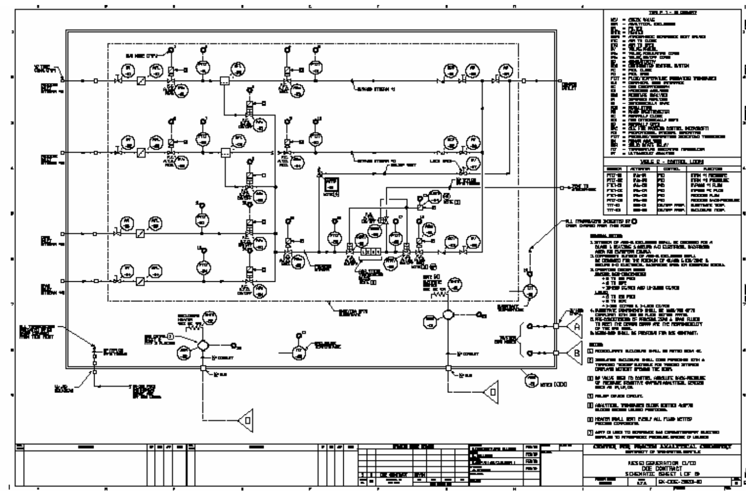


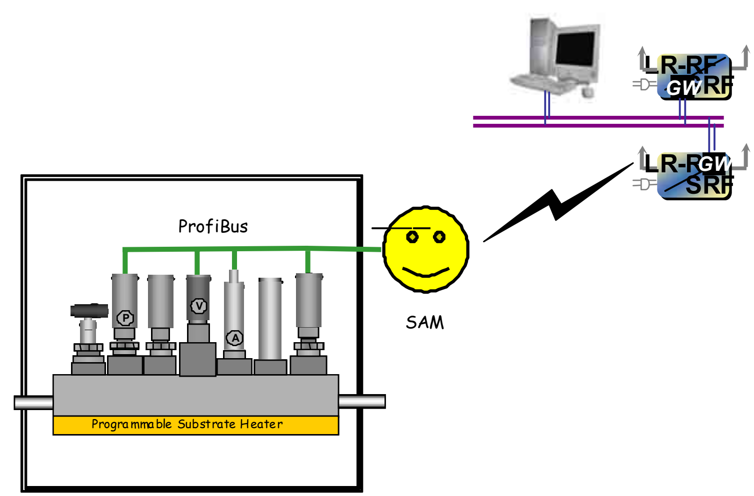
Other Successes

- Wafer-wafer sealing and plugging problem resolved. Yield up from 10 to >75%

Progress to Date – NeSSI Demonstration

- **Extensive investigation of Serial Bus Systems including SDS, CAN, DeviceNet, Foundation Fieldbus, ProfiBus PA, IEEE1451 and Modbus.**
- **Industry and Vendor acceptance of ProfiBus PA physical layer and FISCO Power Architecture for Intrinsically Safe operation.**
- **Future flexibility for Foundation Fieldbus on same physical layer and NIST project to investigate IS CAN technology.**
- **ProfiBus PA chosen for DOE project and endorsed by Vendor and User partners.**
- **Chipsets and software implementations selected & package engineering under way.**
- **Identification and specification parameters for NeSSI compliant conditions sensors.**
- **Identification of analytical and Chemometric sensors for inclusion in NeSSI form.**
- **Selection of key SAM (Sensor Actuator Manager) functions and specifications:**
  - ProfiBus PA interface, 2 channels
  - Ethernet Interface
  - Wireless interface for local PDA
  - Wireless interface to Plant-wide network
  - OPC Server
  - Web Browser Access





Commercialization Plans

- **Users from the chemical, petrochemical, pharmaceutical, metals, food and pulp-and-paper have signed up to participate in the design, preparation and performing field evaluation of NeSSI platform with PHASED sensor.**
- **Honeywell Sensing and Control Division has planned and is implementing Networked Sensor Program for NeSSI**
  - Design of schematics
  - Vendors identified
  - Development team in place
- **Released Honeywell's first industrial wireless sensor system (XYR5000). DOE Team fully integrated to Honeywell's future product development plans. System architecture designed around set of documented interfaces to encourage standardization.**

Future Plans

Industrial Wireless

- Complete designs of top candidate wireless solutions
- Complete development of sensor network candidate solutions
- Install and test sensor systems for operation in live industrial environments

PHASED

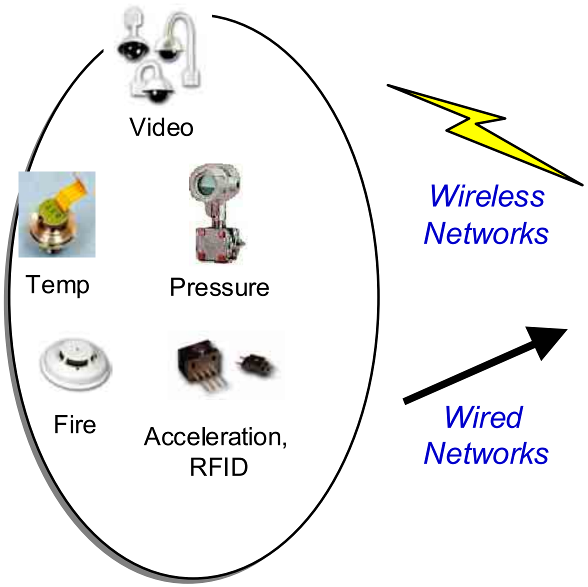
- Separator and preconcentrator materials
  - Complete capillary-based stationary phase film study
  - Address H2O sensitivity
  - Investigate alternative preconcentrator materials
- Complete 2nd process run fab and evaluation
- Optimize electronics package
  - Improve timing sequencing incl. clean/soak cycles
  - Onboard flow sensors
  - Improve detector signal-to-noise and detector thermal isolation
- Continue MEMS separation performance studies
  - Peak identification
  - Separator thermal programming
- Resolve heater membrane stress issues

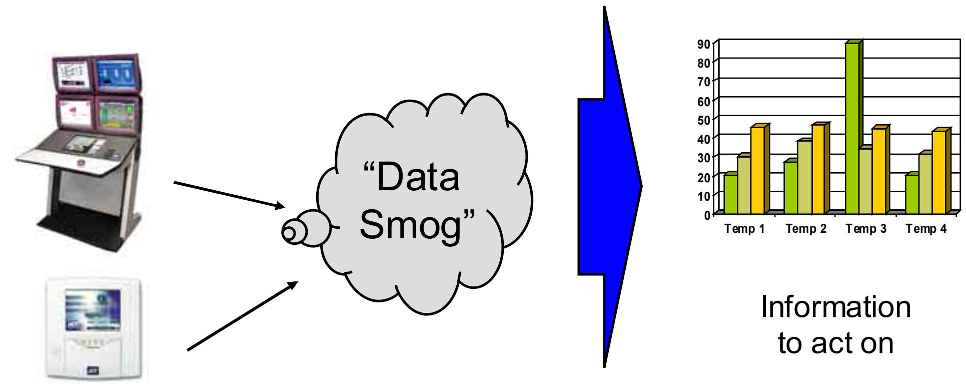
NeSSI

- Deliver, install, and analyze sensor sampling systems

Industrial Wireless Backup

Three Technologies for Pervasive Sensors





Emerging Knowledge Services

- Emerging data mining applications to convert data to useful information. e.g..

Integrated Systems

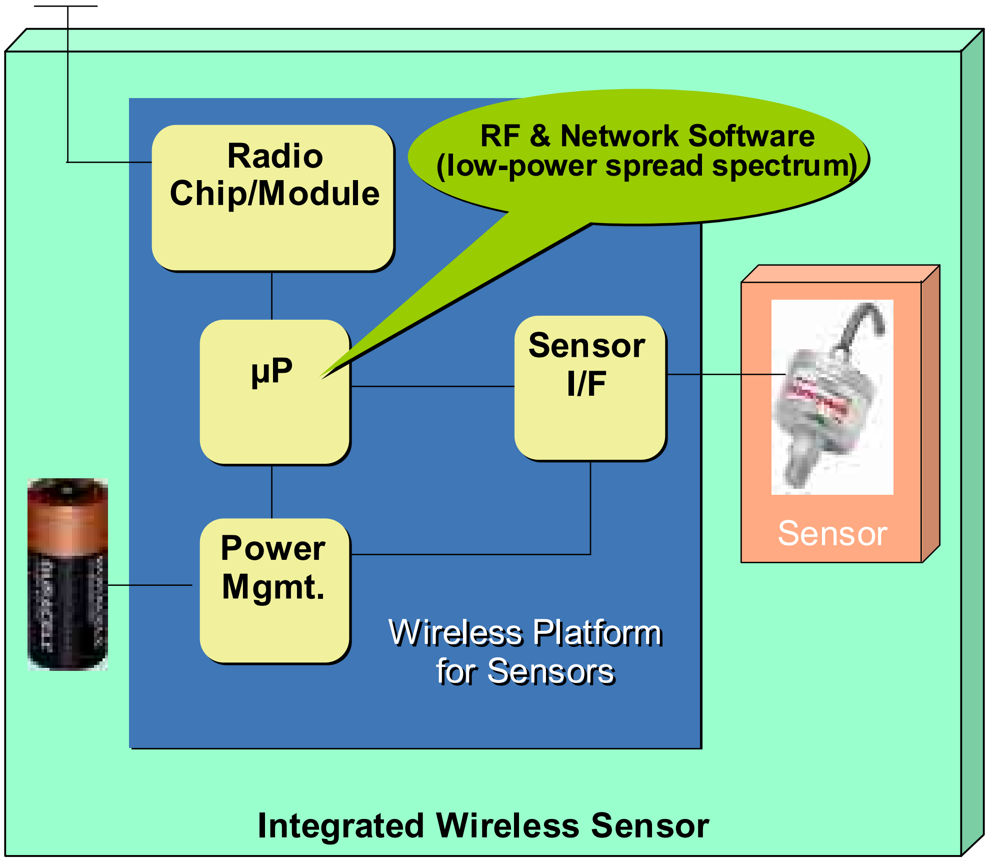
Secure scaleable platforms with open/wireless communications architecture to gather, control, and share data

Sensors and Wireless

- Reliable Wireless a key to make "traditional" sensors in Plants and Buildings pervasive
- New technology sensors - Image based sensors, MEMS, IR Gas Detection for Auto, Medical, Infotech applications.

Evolution towards Pervasive Sensors creates new opportunities in Sensors, Wireless, Integrated Systems, and Knowledge Services

Wireless Sensor Platform

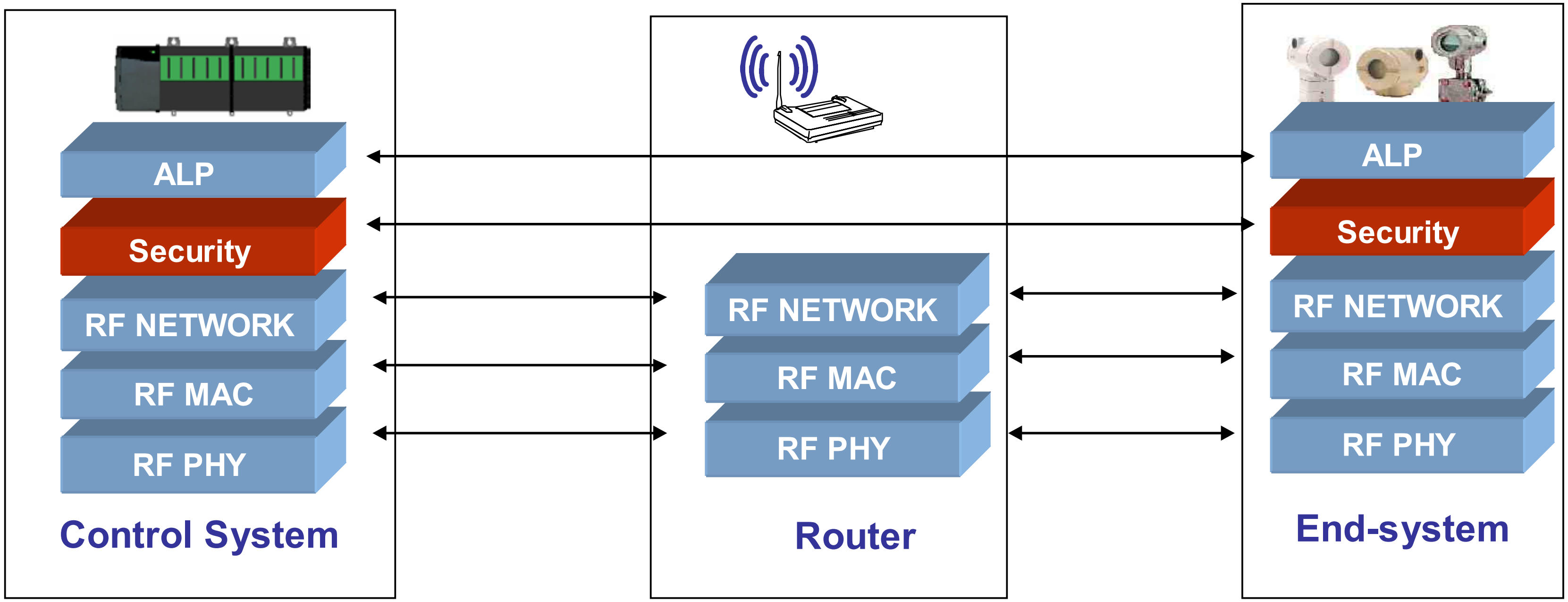


The selected radio design will be integrated with various sensors

The wireless platform for sensors provides a low-power radio, power source, sensor interface electronics and a microprocessor with RF and network software.

An integrated wireless sensor further combines a power source, antenna and a sensor into a single device.

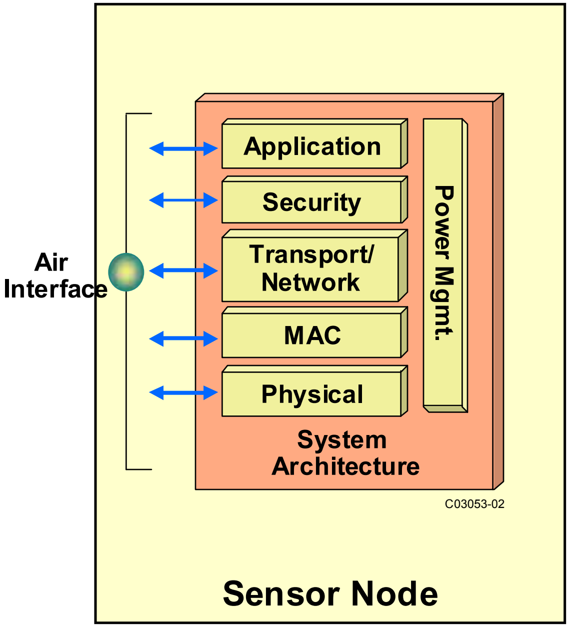
End-to-end Secure Wireless Communications

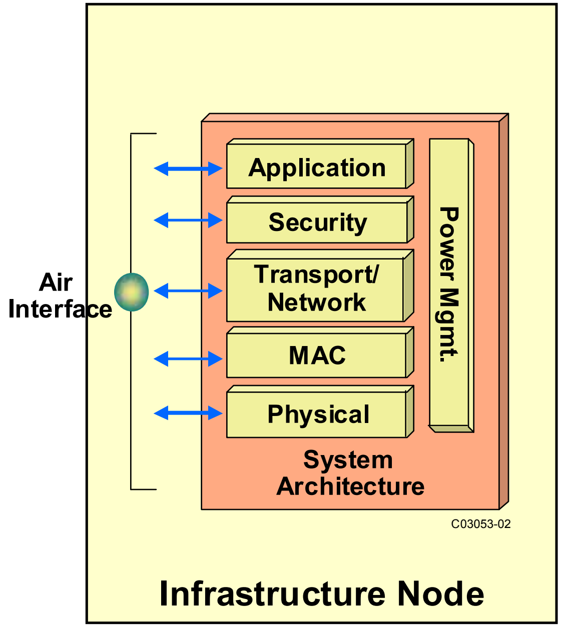


Small footprint embedded security for wireless devices

- Authentication **-- verification of the identity of the remote device**
- Integrity -- **verification that message contents are not modified by a 3rd party**
- Confidentiality **-- Messages in transit cannot be read by third parties.**
- Key Management **-- Shared secrets (high entropy keys) are established and updated reliably, securely conveniently**

Interoperability Objectives





WINA
WIRELESS INDUSTRIAL NETWORKING ALLIANCE

ZigBee Alliance

P1451.5 Scope

Interoperability among multiple vendor products is essential in order to significantly enable the Industries of the Future to realize ubiquitous sensing.

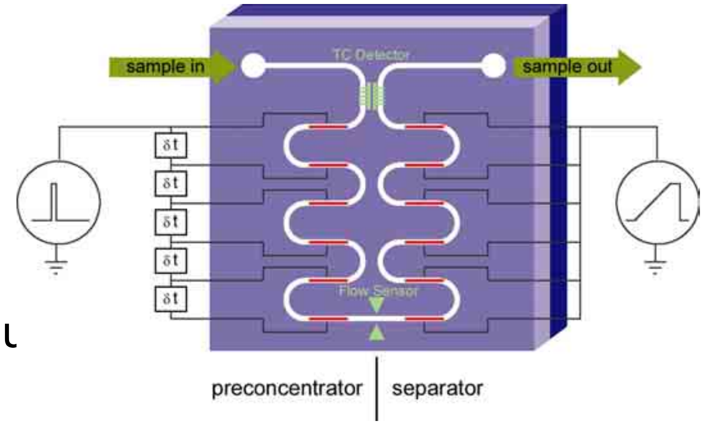
The air interfaces for each layer of the architecture will be documented for future standardization

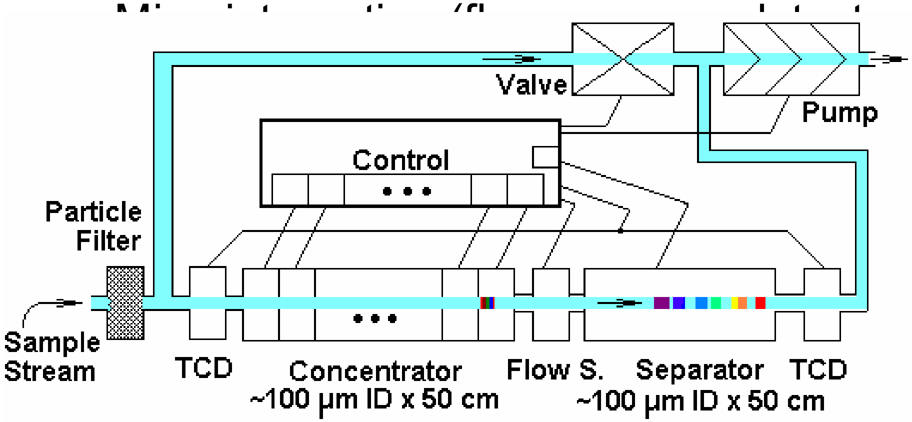
Plan to use ZigBee as much as possible

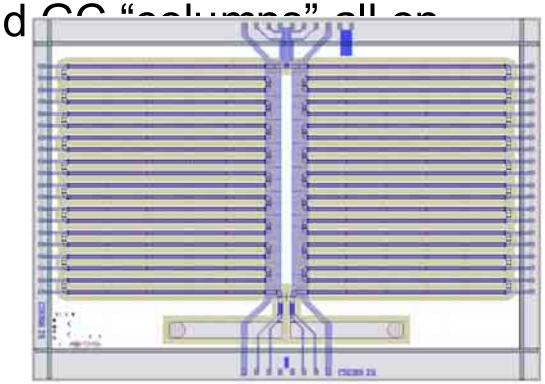
Leverage WINA to create market presence

PHASED Micro Gas Chromatograph Backup

- MEMS Based Micro Gas Chromatograph
  - –Real-Time, Online Measurement of Process Chemistries
  - –Low Power
  - –Low Maintenance (air carrier gas)
- Innovative Technologies
  - – Fast multi-stage pre-concentration
  - – Valve-less sample injection
  - – Orthogonal, low-mass, thermally isolated colu
  - – Millisecond thermal response
  - –10x lower power than std. GC
  - –Tailored nano-engineered separation films
  - , and







20-Element Pre-Concentrator, Diff. TC, 20-Element Separator

FIG. 1. Layout of Integrated Version of the PHASED-II Chip

• PHASED - NeSSi Compatible Packaging

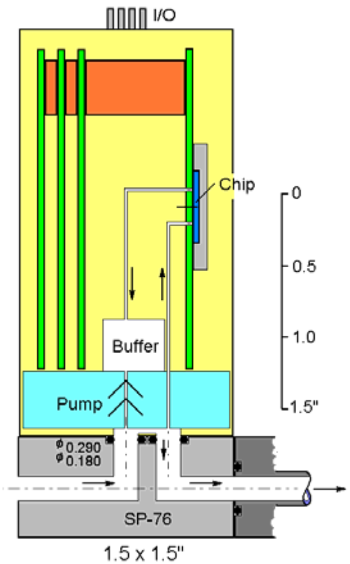


Fig. 2. Crossection of PHASED on a SP-76 Substrate of NeSSI, Conceptual

PHASED MicroGas Analyzer Concept on a SP-76 NeSSI Substrate

- ProfiBus Connector
- PHASED Micro-GC

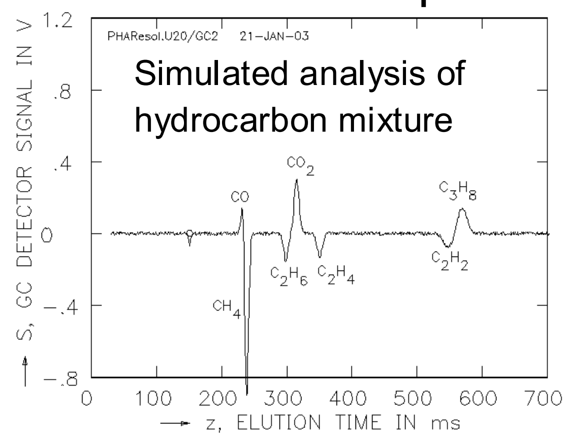
~10 x 15 mm
50-stage-pre-concentrator
Electronic injector
Separator
Flow, temperature TCD
TC Detectors

- Control Electronics

- 1.5 x 1.5” Substrate w/sample I/O

Performance Goals:

•Overall Size:	220 cm3
•Total Analysis Time:	≤ 4sec
•Total Energy/Analysis:	~10J
•Min. Detection Limit:	10ppb
•Detectors MDL:	10ppm
•Preconcentration gain:	≥10,000



2004 Results

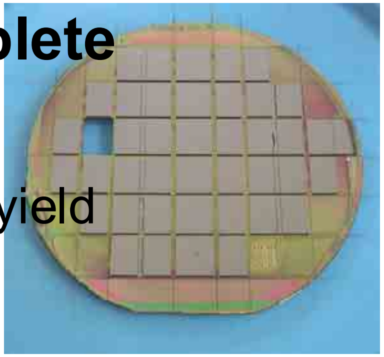
• PHASED Chip Fabrication and Testing

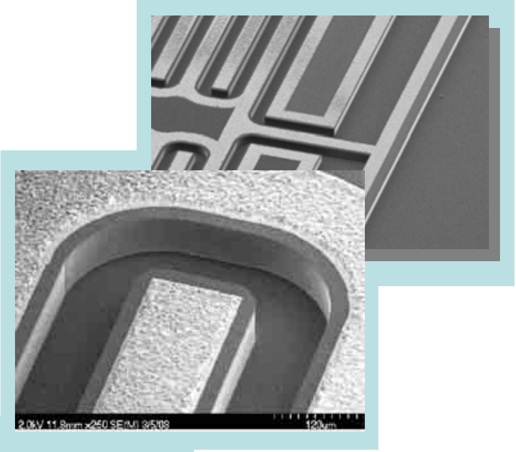
- **Established evaluation testbed**
- **1st pass fab and eval complete**
  1) Poor wafer sealing
  2) Heater current crowding
  3) Low wafer-to-wafer bonding yield

2nd pass design complete

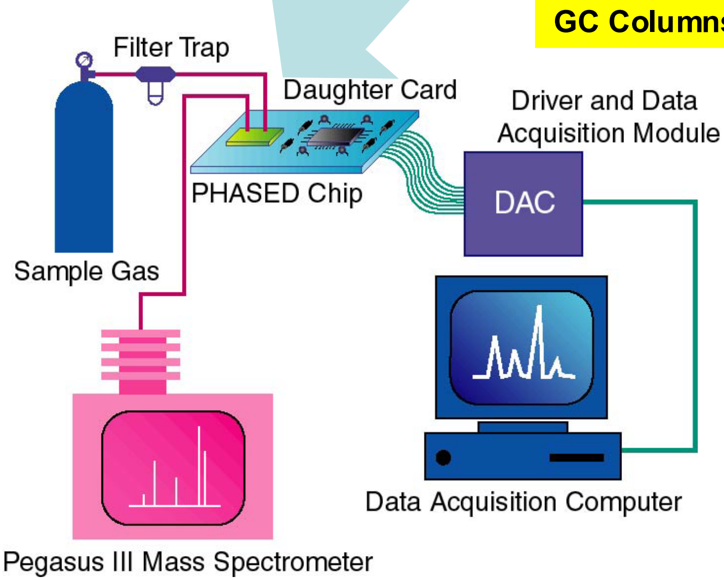
2nd pass fab in process
- Issues 1-3 solved
- Improved stationary phase

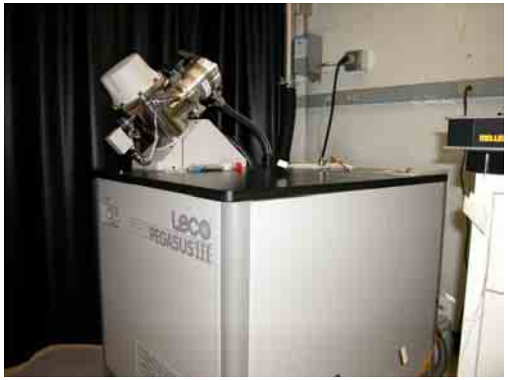
Development, evaluation, and data analysis continuing





GC Columns



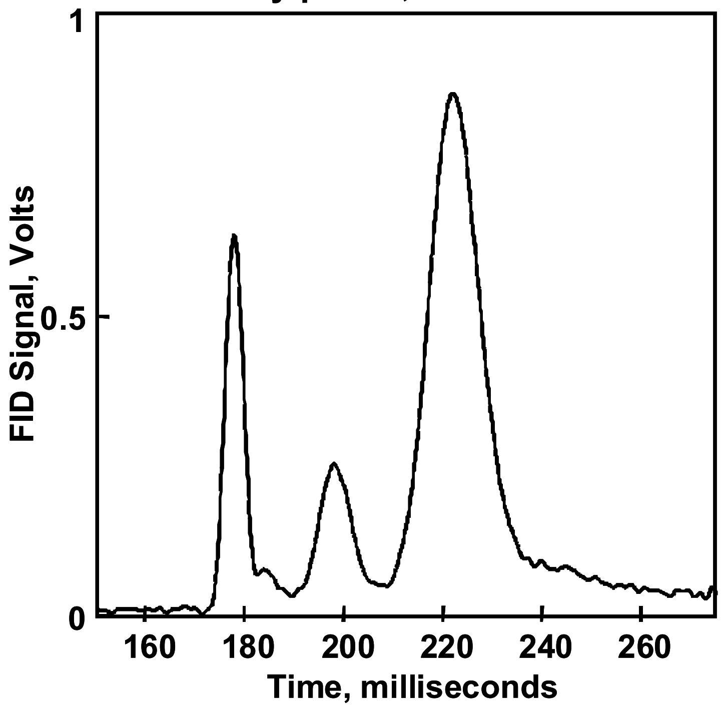


2004 Results

•Stationary Phase Material Development

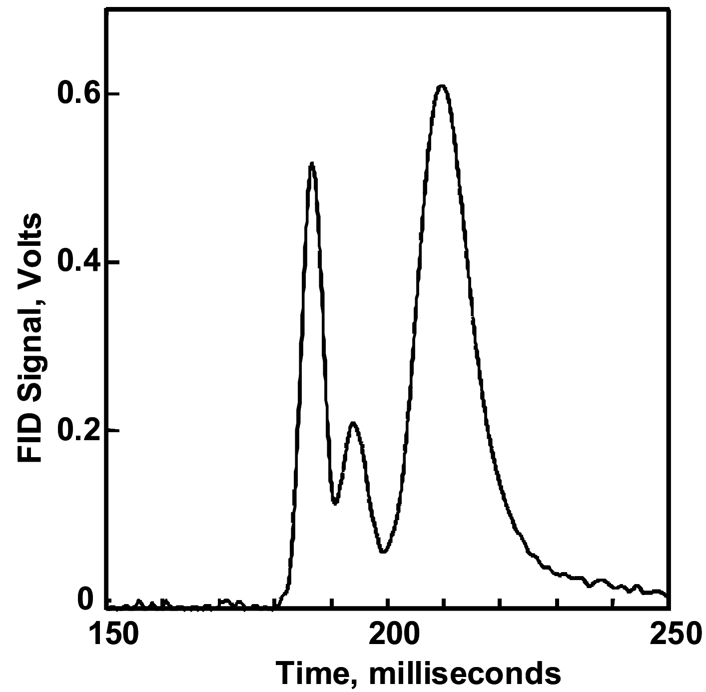
Commercial Benchmark

DB-5 stationary phase, 0.4 micron film thickness



Candidate Material

Porous silica phase of ~5 μm thickness



Performance comparable to commercial benchmark when evaluated in standard GC column

<u>Instrumental Parameters</u>

Oven:25 °C

FID Detector: 250 °C

Column: 1 m, 100 μm ID

Inlet: 250 °C with 10 psi to the valve

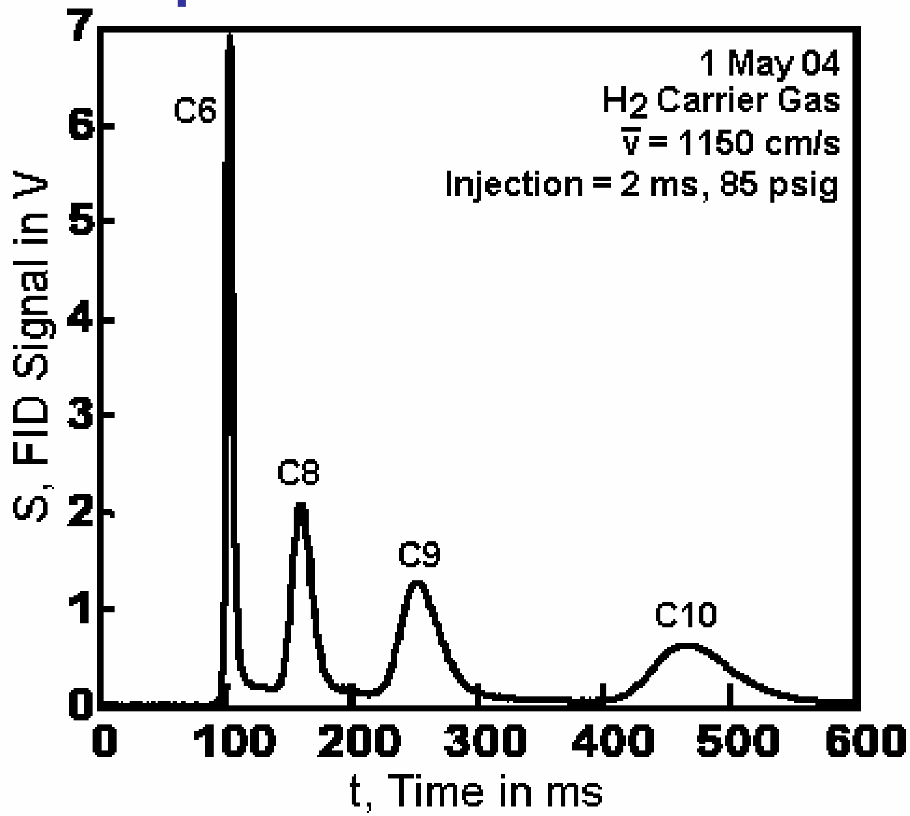
Column Pressure: 35 psi (~700 cm/sec)

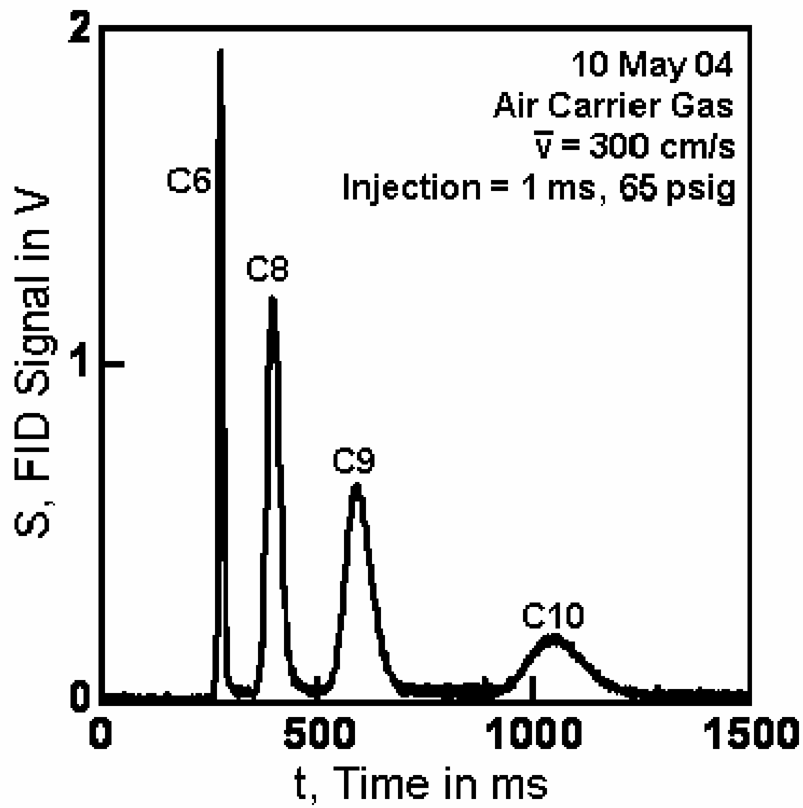
Sample: methane, propane, butane

*Evaluation Data Courtesy G.Gross and R.Synovec, CPAC

2004 Results

•Separation Performance: H2 vs. Air Carrier Gas





Separation of Hexane, Octane, Nonane and Decane.

Capillary #3: 1-m in length,100 µm ID, 3 µm film, 100°C

FID at 250°C, Data Rate: 20 kHz.

*Evaluation Data Courtesy G.Gross and R.Synovec, CPAC

2004 Results Summary

Preconcentration

- Output Peak Height:
  - Increases as heater pulses increase in temperature
  - Reaches max. height when pulse rate is in synch with flow
  - Agrees qualitatively with modeled behavior
- PC Factor:
  - Increases with pulse height and number of elements
  - Values > 80:1 @ 70°C with H_2O (pk./depl.)

Separation

- Retention time depends on T and mat'l., not on film thickness distribution
- Retention and resolution of candidate stationary phase is comparable to DB-5
- Determined 40-55 kJ/mole heat of adsorption on Honeywell porous silica

Other Successes

- Wafer-wafer sealing and plugging problem resolved. Yield up from 10 to >75%

Issues

- Water retention (despite hydrophobic polysiloxane on porous silica)
- Stress in thin film heater membranes
- TCD sensitivity; delays in detector developments (TCD, MDD)

Short-Term Plan

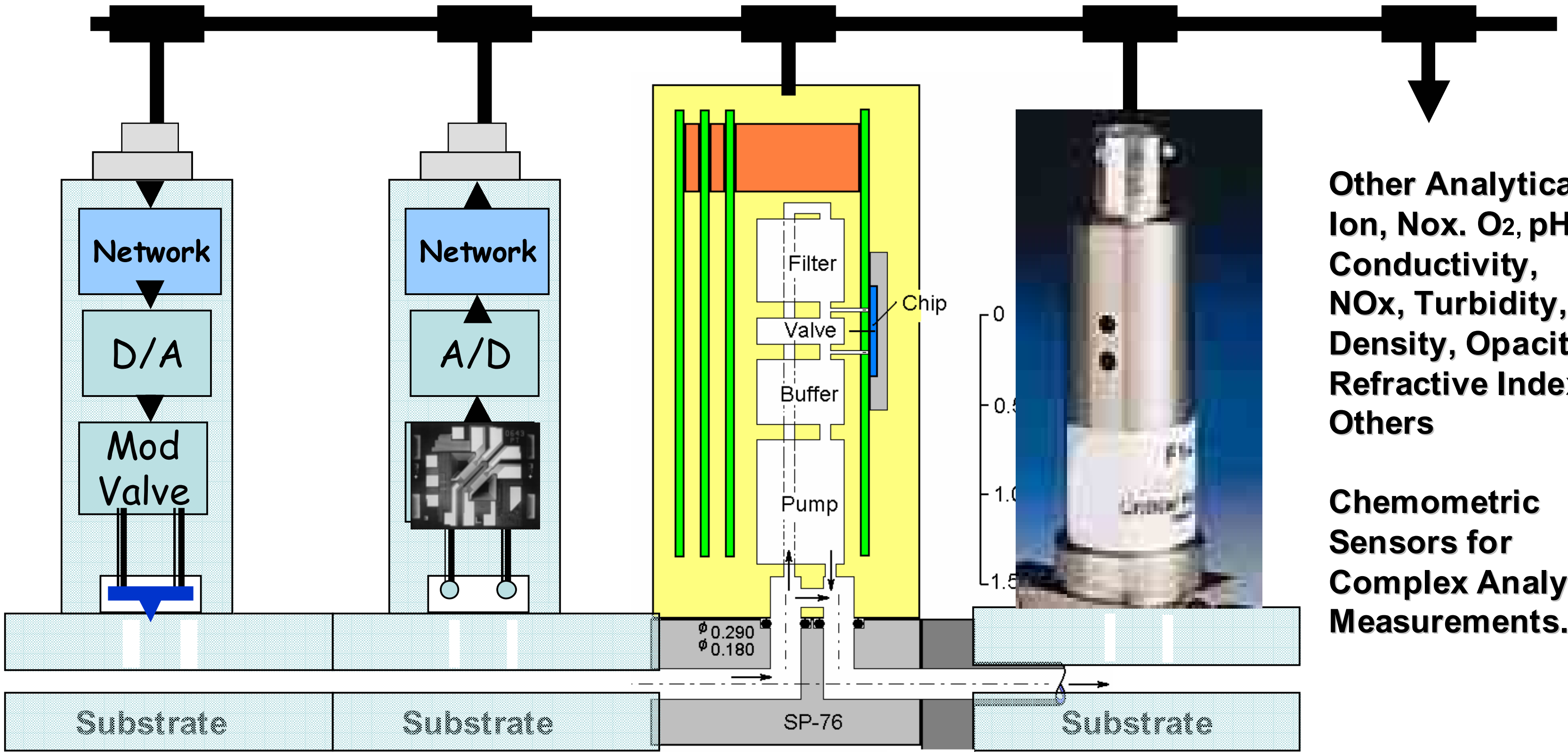
Planned 2004 Activities

- **Separator and preconcentrator materials**
  - Complete capillary-based stationary phase film study
  - Address H_2O sensitivity
  - Investigate alternative preconcentrator materials
- **Complete 2nd process run fab and evaluation**
- **Optimize electronics package**
  - Improve timing sequencing incl. clean/soak cycles
  - Onboard flow sensors
  - Improve detector signal-to-noise and detector thermal isolation
- **Continue MEMS separation performance studies**
  - Peak identification
  - Separator thermal programming
- **Resolve heater membrane stress issues**

NeSSI Demonstration Backup

NeSSI II/III – Network and Sensor Development

Typical NeSSI Device combines state-of-the-art combi- sensor technology with Intelligence and an Intrinsically Safe ProfiBus PA network interface in one small, surface-mount package.



On/Off and Modulating valves

Flow Sensor w/ Temp, Pressure w/ Temp

PHASED Micro GC

Moisture in Dry Gasses

Other Analytical:
Ion, Nox. O_2, pH Conductivity, NOx, Turbidity, Density, Opacity Refractive Index, Others

Chemometric Sensors for Complex Analytical Measurements.

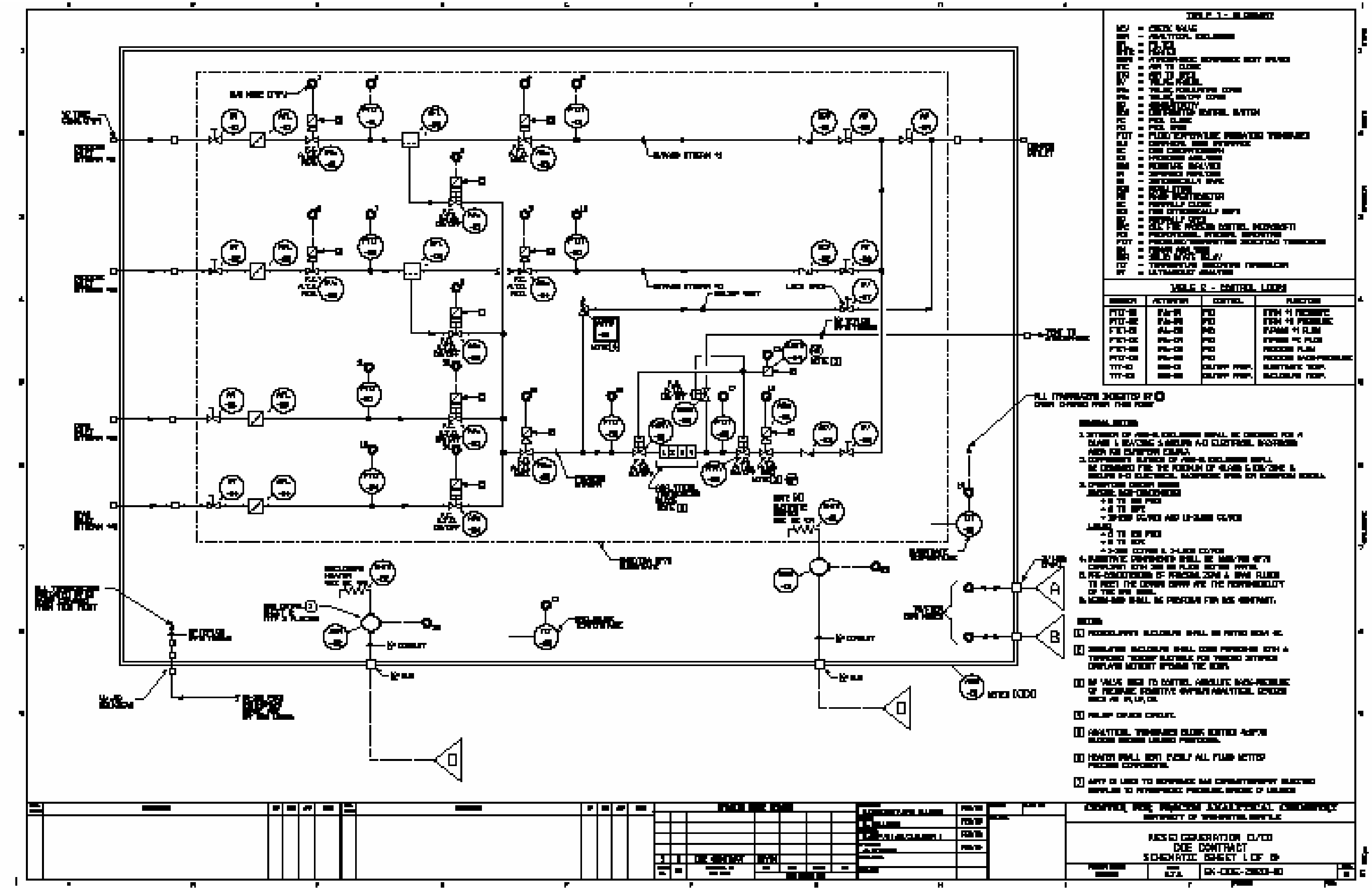
NeSSI Cross-Cutting Field Test Team

Users	Applications
• AirProducts	He/H_2 purification, metal heat treating
• Dow-Chem.	Ethylene plant, water treatment
• DuPont	Particle drying
• Exxon-Mobil	Chemical and petrochemical
• **Honeywell** SM	Refrigerant distillation
• UOP	Combustion control
• UW (CPAC)	Application studies

Suppliers

- Honeywell, Swagelock, Parker, Celerity, Circor, ….

3-Stream NeSSI Design for Cross-Cutting Field Tests



NeSSI Field Test Evaluation Criteria

Technical

1. **Sensing and control of p, T and F, over specified p, T, F ranges**
2. **Performance relative to existing technology**
3. **Capability to upgrade on-site**
4. **Technology: The "gee-wiz" factors**
5. **Analyzer output usefulness****

Business

1. Cost to buy
   1.1 New unit
   1.2 Upgrade/replace existing technology
2. Cost to install (Hazard.Op.-to-Readiness Inspection/ training / documents / P&ID)
3. Cost to maintain (materials and labor)5.
4. Impact on product/process for cost to make goods
   6.1 Safety
   6.2 Production energy use

**Especially the NeSSI feature enabling use of sensors selectable from a menu of NeSSI-compatible sensors of fluid-stream properties (besides flow, pressure and temperature): Thermal and elecrical conductivity, pH, density, viscosity, concentrations of oxygen, humidity, etc.; dielectric constant, refractive index, ...

Programmatic Merit of PHASED and NeSSI

Summary of DoE Energy Savings Calculator Results

Application	Industry Group (NAICS Codes)	Type of Savings	2010 Savings (TBtu)	2015 Savings (TBtu)	2020 Savings (TBtu)
Ethylene Production	324110	Upset Avoidance & Process Improvement	2.14	10.26	18.25
Metals Processing	331, 332	Waste Avoidance	2.45	6.96	16.20
Hydrogen Production	325	Process Improvement	0.52	2.73	5.35
TiO_2 Drying	325	Process Improvement	0.01	0.04	0.06
Fired Heaters	324110	Process Improvement	2.14	10.26	18.15
Aluminum Production	3313	Process Improvement	0.39	1.12	2.61
Pulp Production	322110	Process Improvement	0.45	2.06	3.49
TOTAL			8.10	33.42	64.10
Petroleum Refining	324110	Upset Avoidance & Process Improvement	18.59	86.48	149.36
Metals	331, 332	Waste Avoidance	4.41	12.54	29.20
Chemicals	325	Process Improvement	7.95	38.13	67.83
Pulp Mills	322110	Process Improvement	1.06	4.84	8.19
TOTAL			32.01	141.99	254.58
TOTAL SAVINGS @ $6/10^6 Btu, in B$			0.19	0.85	1.53
SAVINGS TO TOTAL IND. CONSUMPTION IN %			0.13	0.60	1.07